

**APPENDIX C-3. ESTIMATES OF MANUFACTURING COSTS AND ENERGY
CHARACTERISTICS FOR ELECTRIC AND GAS-FIRED STORAGE WATER
HEATERS: DATA FROM MAX MINNIER AND OTHER SOURCES**

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APPENDIX C-3. ESTIMATES OF MANUFACTURING COSTS AND ENERGY CHARACTERISTICS FOR ELECTRIC AND GAS-FIRED STORAGE WATER HEATERS: DATA FROM MAX MINNIER AND OTHER SOURCES

This Appendix documents the manufacturer cost data for residential electric and gas-fired^a water heaters provided to the U.S. Department of Energy by Max E. Minniear, consultant to Lawrence Berkeley National Laboratory (LBNL).¹ The data are used in the Engineering and the Life-Cycle Cost analyses to develop the federal efficiency standards for such products.

C-3.1 INTRODUCTION

The primary source of both manufacturer cost and efficiency data for this analysis was the Gas Appliance Manufacturers Association (GAMA), which collected data from water heater manufacturers. GAMA did not provide data for three of the design options being considered (2.5-“ and 3" Jacket Insulation, Plastic Tank, and Side Arm Heater). The missing data were obtained from Minniear, former Vice President of Engineering at A.O. Smith Water Products Company, who was contracted by LBNL to provide disaggregated cost and efficiency data for baseline designs and various design options. Some of the cost data were compared to data obtained from Eugene West, formerly of Bradford-White Corporation, who was under contract with Pacific Northwest National Laboratory (PNNL).² Both consultants were recommended by GAMA.

Minniear's data were used primarily for two purposes: 1) to supply the manufacturing data for the missing design options, 2) to confirm the reasonableness of the computer models' estimates used in the analysis and 3) to provide a base for the markup adjustment for gas-fired water heaters when a 4" flue diameter is applied.

C-3.2 DATA

Minniear provided manufacturer cost and efficiency data for both electric and gas-fired water heaters. The data were supplied in the format developed by A.D. Little Company to reflect the basic design options used in the analysis.

Electric Water Heaters: For the typical existing baseline 50-gal electric water heater, Minniear provided total manufacturing cost data. He also provided the incremental manufacturing cost for each design option.

^a Water heaters fueled by natural gas and LPG are considered as one product class from the point of view of physical and efficiency characteristics. They are treated separately with respect to manufacturing cost, markup, retail price, and fuel price in the Life-Cycle Cost and subsequent analyses.

Table C-3.1 contains the manufacturing costs and the associated uncertainty ranges for electric water heaters and Table C-3.2 contains the energy characteristics values and the associated uncertainty ranges.

Gas-Fired Water Heaters: For the typical existing baseline 40-gal gas-fired water heater, Minniear provided total manufacturing cost data. He also provided the incremental manufacturing cost for each design option.

Table C-3.3 contains the manufacturing costs and the associated uncertainty ranges for gas-fired water heaters and Table C-3.4 contains the energy characteristic values and the associated uncertainty ranges.

Cost Difference Estimate for Gas-Fired Water Heaters with 4" and 3" Flues: For the typical existing baseline 30-gal and 40-gal gas-fired water heater, Minniear provided incremental manufacturing cost data to account for the price impact of a change in the flue diameter from 4" to 3". The cost increment is based solely on the impact of a change in the flue diameter.^{3,4}

In the case of the 30-gal water heater, it was assumed that both water heaters (3" and 4" flue diameters) use HCFC-141b-based insulation, have a 14-in. diameter tank, and a 1-in. nominal jacket cavity. Similar assumptions were used for the 40-gal water heater with the exception of a 16-in. diameter tank. Both 30- and 40-gal water heaters use the same gas valve and burner components even though they have different energy inputs.

The reduction in the flue diameter has the following effect on water heater design: the width of the baffle is decreased, the diameter of the material used to fabricate the flue is decreased, the draft hood must be redesigned for the smaller flue, and the height of the tank is decreased to maintain the same volume. The design changes reduce the amount of steel used in the shell, the amount of steel used in the flue, the amount of steel used in the jacket, the amount of foam used in the sidewall, the amount of material used in the dip tube, the amount of material used in the anode rod, the length of the baffle and the amount of steel used in the baffle, and the material used in the carton (the tank itself and the shipping carton are about 1-3/4" shorter than a unit with a 4" flue). The change in flue diameter has no impact on components such as foam dams, burners, gas valves, drain valves, etc. There is no perceivable difference in direct or indirect labor. Table C-3.5 contains the incremental variable material cost estimates for 30-gal and 40-gal gas-fired water heater due to a change in the flue diameter from 4" to 3". As can be seen in the table, the totals are \$2.26 for 30-gal and \$2.11 for 40-gal water heater.

In order to determine the markup of the 3" water heater (by adjusting the costs of the 4" case), *all* of the cost components of the base 4" water heater must be included in the adjustment. This includes the manufacturer's cost allocations and product failure costs.⁵

Most manufacturers use cost allocations to distribute the fixed costs across the product line. Cost allocation is part of the water heater fixed costs. The total variable manufacturing costs determine the magnitude of the allocation cost. Water heaters with lower variable costs absorb

proportionately less fixed cost. In this case, the 3" flue water heater would absorb about \$1.05 less fixed costs than the 4" flue case. Therefore, the impact of correcting the fixed cost absorption would further reduce the manufacturing cost of a 3" flue water heater by \$1.05.

Product failure cost (also part of the fixed cost) must also be adjusted for a 3" flue water heater. Product failure cost is based on three elements:

- product reliability,
- manufacturer liability, and
- replacement cost in case of failure.

Product reliability is a weighting factor. If a product is more likely to fail within the warranty period, more monies would be allocated to manufacturer warranty reserves.

Manufacturer liability is a simple allocation much like fixed cost and is based on the cost of the product. If the product costs more, the liability increases. The products being considered (4" vs. 3" flue diameter water heaters) would not have a significant difference in liability so that part of the product failure cost would remain unchanged.

The replacement cost is based on the manufacturer's cost of the water heater. As the variable manufacturer cost increases so does the amount allocated to cover the future warranty cost.

Based on the lower cost of the 3" flue water heater, less would be allocated for product failure. Correcting for this reduced product failure cost further reduces the manufacturing cost of a 3" flue water heater by \$0.24.

The total cost adjustment for the 3" flue diameter water heater as compared to a similar 4" water heater is \$3.40 for the 40-gal and \$3.64 for the 30-gal water heater.

Cost Difference Estimate between LPG and Gas-Fired Water Heaters: For the typical existing baseline 40-gal gas-fired water heater, our consultant provided incremental manufacturing cost data to account for the price impact of a change from natural gas to LPG.⁶

It was assumed that both water heater types (natural gas and LPG fuel) use HCFC-141b-based insulation, have a 16-in. diameter tank, and a 1-in. nominal jacket cavity.

The fuel change from natural gas to LPG has the following effect on water heater design: the gas thermostat/valve is fuel-specific, the LPG water heater uses a smaller main orifice (the reason is that the rate of gas flow in ft³/hr is less for LPG because of the higher energy input in Btu/ft³), and the LPG water heater uses a smaller pilot orifice. The design changes increase the cost of all three components: the main gas thermostat/valve, the main orifice and the pilot. Table C-3.6 contains the incremental variable material cost estimates for 40-gal gas-fired water heaters due to an LPG fuel change. As can be seen in the table, the total material cost is \$9.20.

The total incremental manufacturing cost includes also a fixed cost component as well as product failure and liability allocations. The liability cost allocation is based on the basic cost of the product regardless of fuel type. This includes natural gas, LPG, and electric. The normal liability allocation should be adjusted for the difference in material and labor cost. In this case, there is no difference in labor cost. The LPG water heaters have a significant difference in liability and in this case the incremental liability cost is be \$0.40.

The total cost adjustment for the 40-gal LPG water heater as compared to a similar natural gas water heater is \$14.82.

Table C-3.1 Manufacturing Cost - Electric Water Heaters (50-gal)

Design Options	Variable Costs ¹				Cost Uncertainty Range	Fixed Costs ^{2,3}			Cost Uncertainty Range
	Material \$/unit	Labor \$/unit	Overhead \$/unit	Total \$/unit		Capital \$ Million	Product Design \$ Million	Total \$ Million	
1 Baseline	58.43	5.77	18.11	82.31	1% 1%	0.00	0.00	0.00	– –
2 Heat Traps ⁴	2.00	0.05	0.15	2.20	1% 1%	0.01	0.01	0.02	1% 1%
3 Increased Insulation (R-24 Foam) ⁵	8.50	0.15	0.45	9.10	5% 2%	0.02	0.04	0.06	3% 2%
4 Increased Insulation (R-32 Vacuum) ⁶	20.00	0.50	1.50	22.00	15% 5%	0.16	0.16	0.32	20% 20%
5 Plastic Tank ⁷	5.25	0.80	3.20	9.25	5% 5%	0.60	0.12	0.72	10% 5%

¹ The total variable cost includes material, labor, and overhead cost. The overhead is only the factory overhead

² Conversion cost - million \$/40,000 units

³ There is no fixed cost associated with the existing baseline model

⁴ Heat Traps design option cost is assumed to be one and same for all types of heat traps

⁵ R-24 is equivalent to 3 inches of polyurethane foam

⁶ R-32 is equivalent to a vacuum insulation

⁷ Cost for plastic tank design option reflects the “steel shell/plastic interior” tank method used in the analysis

Table C-3.2 Energy Characteristics - Electric Water Heaters (50-gal)

	DOE Design Options	Energy Data				Uncertainty Range	
		EF	RE	U A	On-Cycle	Off-Cycle	EF (+/- percentage)
					Elec W	Elec W	
1	Baseline	0.900	0.98	5.50	4400	0	0.902 0.875
2	Heat Traps	0.905	0.98	5.25	4400	0	0.907 0.890
3	Increased Insulation (R-24 Foam)	0.935	0.98	4.00	4400	0	0.937 0.900
4	Increased Insulation (R-32 Vacuum)	0.955	0.98	3.30	4400	0	0.960 0.900
5	Plastic Tank	0.910	0.98	5.00	4400	0	0.920 0.900

Table C-3.3 Manufacturing Cost - Gas-Fired Water Heaters (40-gal)

DOE Design Options		Variable Costs ¹				Cost Uncertainty Range		Fixed Costs ^{2,3}			Cost Uncertainty Range	
		Material \$/unit	Labor \$/unit	Overhead \$/unit	Total \$/unit	Variable Costs (+/- percentage) Max. %	Min. %	Capital Million \$	Product Design Million \$	Total Million \$	Fixed Costs (+/- percentage) Maximum %	Minimum %
1	Baseline	64.53	6.50	16.72	87.75	1	1	0.00	0.00	0.00	—	—
2	Heat Traps ⁴	2.00	0.05	0.15	2.20	2	2	0.01	0.01	0.02	2%	2%
3	Increased Insulation (R-16 Foam) ⁵	6.00	0.05	0.15	6.20	5	5	0.02	0.02	0.04	4%	2%
4	Increased Insulation (R-24 Foam) ⁵	14.50	0.15	0.45	15.10	10	5	0.04	0.06	0.10	5%	2%
5	Plastic Tank ⁷	29.75	2.90	9.25	41.90	10	5	0.80	0.40	1.20	10%	5%
6	Improved Flue Baffle	1.25	0.15	0.45	1.85	5	5	0.07	0.15	0.22	5%	2%
7	Multiple Flues	13.25	0.65	2.25	16.15	5	5	0.75	0.15	0.90	5%	2%
8	Improved Combustion Chamber				0.00					0.00		
9	Submerged Combustion Chamber	17.25	1.75	5.75	24.75	5	5	0.20	1.00	1.20	8%	4%
10	Flue Damper (electro-mechanical)	6.25	0.70	2.25	9.20	10	5	0.03	0.15	0.18	10%	3%
11	Side Arm Heater	24.50	2.10	7.20	33.80	20	10	0.20	0.50	0.70	20%	10%
12	Two Phase Thermosiphon	12.25	1.15	3.20	16.60	20	10	0.04	0.12	0.16	10%	10%
13	IID	14.50	1.25	4.50	20.25	10	5	0.07	0.10	0.17	5%	5%

¹ The total variable cost includes material, labor, and overhead cost. The overhead is only the factory overhead

² Fixed costs - million \$/50,000 units

³ There is no fixed cost associated with the existing baseline model

⁴ Heat Traps design option cost is assumed to be one and same for all types of heat traps

⁵ R-16 is equivalent to 2 inches of polyurethane foam

⁶ R-24 is equivalent to 3 inches of polyurethane foam

⁷ Cost for plastic tank design option assumes that the design has a side arm combustion system with the plastic tank as a storage medium.

Table C-3.4 Energy Characteristics - Gas-Fired Water Heaters (40-gal)

DOE Design Options		Energy Data						Uncertainty Range	
		EF	RE	UA	On-Cycle		Off-Cycle		EF
					Gas Btu/hr	Elec W	Gas Btu/hr	Elec W	(+/- percentage) Max. \$ Min. \$
1	Baseline	0.560	0.75	12.0	40,400	0	400	0	0.565 0.545
2	Heat Traps	0.565	0.75	11.5	40,400	0	400	0	0.575 0.560
3	Increased Insulation (R16 Foam)	0.576	0.75	10.5	40,400	0	400	0	0.580 0.560
4	Increased Insulation (R24 Foam)	0.581	0.75	10.0	40,400	0	400	0	0.585 0.565
5	Plastic Tank	0.644	0.80	7.5	40,400	0	400	0	0.670 0.630
6	Improved Flue Baffle	0.595	0.79	11.0	40,400	0	400	0	0.600 0.580
7	Multiple Flues	0.568	0.80	14.0	40,400	0	400	0	0.575 0.555
8	Improved Combustion Chamber								
9	Submerged Combustion Chamber	0.583	0.77	11.0	40,400	0	400	0	0.590 0.575
10	Flue Damper (electro-mechanical)	0.604	0.75	8.0	40,400	30	400	0	0.606 0.585
11	Side Arm Heater	0.637	0.80	8.0	40,400	0	400	0	0.645 0.620
12	Two Phase Thermosiphon	0.560	0.75	12.0	40,400	0	400	0	0.565 0.545
13	IID	0.565	0.75	11.5	40,000	15	0	5	0.565 0.560

Table C-3.5 Incremental Manufacturing Cost for 3" vs. 4" Flue Diameter - Gas-Fired Water Heaters (30-gal and 40-gal)

Components ¹	30-gal \$	40-gal \$
tank shell	0.44	0.37
flue	1.15	1.12
jacket	0.13	0.10
baffle	0.13	0.13
foam	0.08	0.07
dip tube	0.05	0.05
anode rod	0.12	0.12
carton	0.11	0.10
draft hood	0.05	0.05
Total	2.26	2.11

¹ The incremental costs are based on a cost of steel of \$0.25/lb and \$1.00/lb for polyurethane foam.

Table C-3.6 Incremental Manufacturing Cost for LPG Water Heaters (40-gal)

Cost Components	40-gal \$
Material cost	9.20
Fixed cost	4.56
Product failure	0.66
Liability	0.40
Total	14.82

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